Trace Metals in Edible Clams from King County Beaches

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Introduction

Bivalves are frequently used as indicator organisms for environmental measurements in aquatic environments as they tend to accumulate pollutants in their tissues, a process known as bioaccumulation. The amount of pollutants bioaccumulated is a concern as bivalves may be consumed by humans and wildlife. King County has monitored organic compounds, trace metals, and bacteria in bivalve tissues at designated King County beaches for the past several years.

The primary objective of King County's shellfish monitoring program from 1993 to 1996 was to comply with the County's National Pollutant Discharge Elimination System (NPDES) permits for the East Division Reclamation (Renton), West Point, and Alki Sewage Treatment Plants and the Carkeek Combined Sewer Overflow Treatment Plant. The East Reclamation and West Point Treatment Plants discharge secondary treated effluent into the central basin of Puget Sound, whereas the Alki plant discharges sanitary sewer/stormwater primary treated effluent into the central basin. Sample sites were chosen based upon their proximity to treatment plant discharges. Edible bivalves (clams) were chosen as a biomonitor as they are easily obtained and are the main group of organisms recreationally harvested from King County beaches. The primary goal of the monitoring data was to assess pollutant body burdens in edible clams, which may be transferred to both the humans and wildlife that consume them. A secondary goal was to compare the data with results obtained from other studies.

The sampling protocols were designed in order to achieve the primary data goal, which was to assess pollutants bioaccumulated in clams being recreationally harvested. All edible clams collected of sufficient size were composited into a single sample for each site. Thus, the species assemblage differed from beach to beach and from year to year, depending on which edible species were readily available. While this data is useful for determining pollutant burdens to recreational harvesters consuming available clams, it does present limitations. Spatial and temporal comparisons are not possible, because the clam species contained in each sample differed and it has been shown that bioaccumulation rates can differ by species (Phillips & Rainbow, 1993; Faigenblum, 1988).

In this paper, four years of data are presented and discussed for nine trace metals measured in clam tissues collected from eight sites.

Methods

Field Methods

Clams were collected from the following eight beaches in 1993, 1994, 1995, and 1996: Carkeek Park (KSHZ03), Blue Ridge (KSJX02), Golden Gardens (KSLU03), West Point-north of lighthouse (KSSN04), West Point-south of lighthouse (KSSN05), Magnolia (KSUR01), and Alki Point (LSKR01 and LSKS01) (Figure 1). In 1993, clams were collected in September and from 1994 to 1996 they were collected in July. Species composition varied at each beach and species collected (in order of preference) included native littleneck (*Protothaca staminea*), manila (*Venerupis japonica*), butter (*Saxidomus giganteus*), cockle (*Clinocardium nuttalli*), and horse (*Tresus capax*) clams. Only clams of edible size were retained. After digging with a shovel or trowel, clams were sealed in glass jars (plastic bags in the case of large horse clams) and held in ice chests. Clams with chipped or cracked shells were rejected.

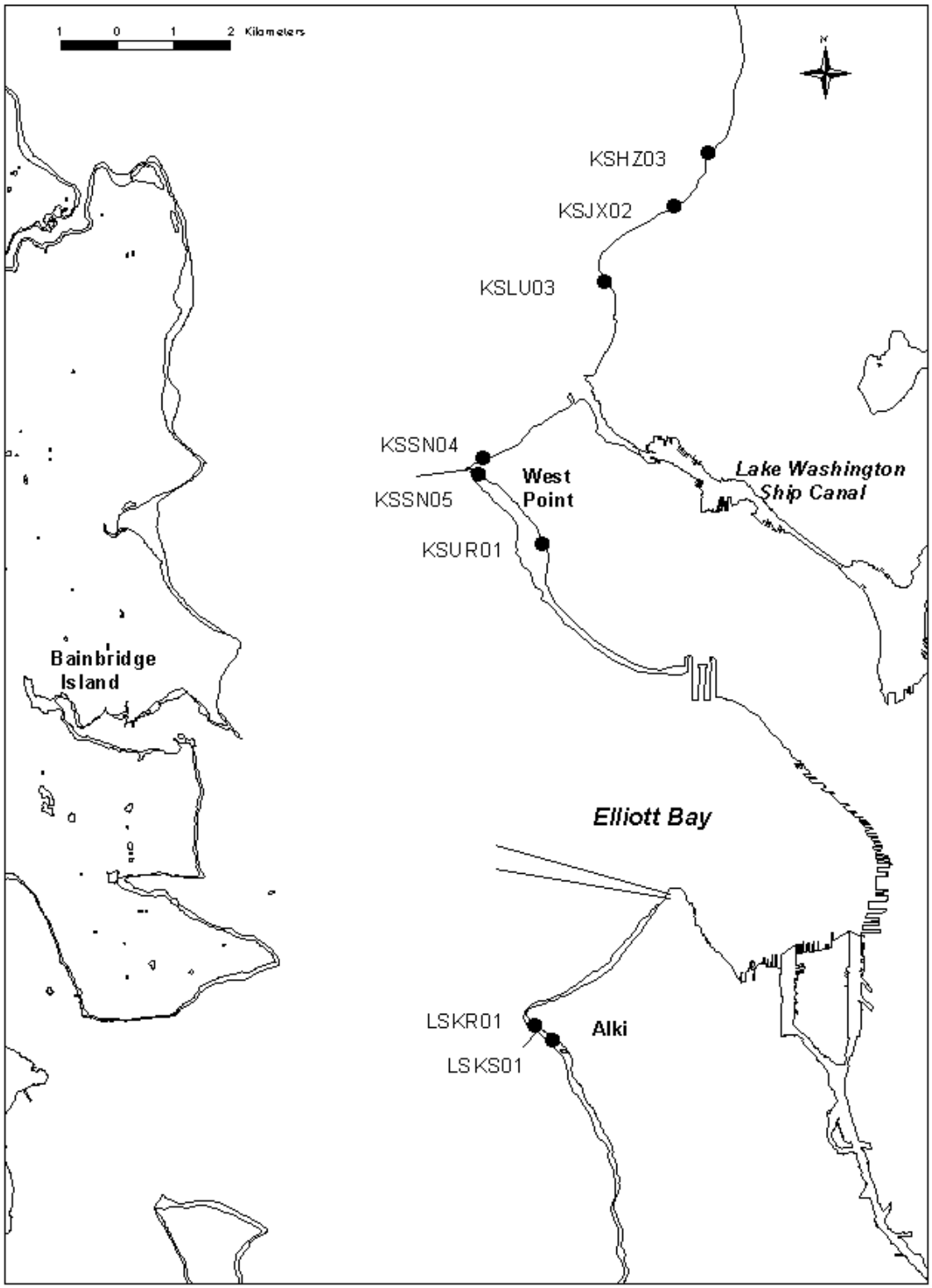

Figure 1. Sample locations.

Laboratory Methods

All clams were shucked and whole tissues were mixed to form a single composite sample in accordance with Puget Sound Estuary Program (PSEP) recommended protocols (PSEP, 1996a). A minimum of 350 grams of tissue was obtained for each site. The tissues were stored frozen in pre-cleaned jars for later analysis.

All metals, with the exception of mercury, were digested using a nitric acid/hydrochloric acid/hydrogen peroxide digestion and then analyzed by inductively coupled plasma emission spectroscopy (ICP). Mercury was analyzed by cold-vapor atomic absorption spectrophotometry following digestion by the nitric acid/sulfuric acid method (PSEP, 1996b). Quality assurance/quality control procedures included the use of blanks, duplicates, and spikes.

Results

Tissue samples were analyzed for 16 metals. However, only arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc are discussed in this paper. Results are reported in mg/kg (ppm) on a wet weight basis and are presented in Table 1.

Arsenic

Between 1993 and 1996, concentrations ranged from 1.0 and 3.4 mg/kg at all beaches. Except for KSSN04, most values were below the laboratory's reported detection limit (RDL) but above the method detection limit (MDL). The maximum concentration (3.4 mg/kg) was detected at stations KSSN04 and KSUR01. Arsenic concentrations detected in clams from King County beaches are similar to concentrations detected in edible shellfish from other studies in Puget Sound (WDOH, 1996; Cubbage, 1991; Faigenblum, 1988).

Cadmium

Cadmium concentrations ranged from below the MDL (0.06) to 0.27 mg/kg. As with arsenic, most values were below the RDL but above the MDL. The highest concentrations were found at station KSHZ03, which had a mean concentration from 1993 to 1996 of 0.21 mg/kg (n = 4).

Chromium

Chromium was detected in all samples collected and ranged from 0.19 to 1.13 mg/kg, with one exception discussed below. Values were above the RDL with the exception of three samples. The results obtained from this study are similar to those from other Puget Sound studies (WDOH, 1996). The value for station KSJX02 in 1994 was 31.30 mg/kg, which was over 26 times higher than the next highest value. The sample consisted of bent-nosed clams, *Macoma nasuta*, which is not a target species because this clam has a different feeding strategy (surface deposit feeder) from the preferred species (filter feeder). It has been shown that *Macoma spp.* bioaccumulate copper and zinc more than other clam species and as this data suggests, chromium as well (Faigenblum, 1988). Therefore, this value will not be included in further discussions.

Copper

Copper was detected in all samples above the RDL. Concentrations ranged from 0.89 to 5.10 mg/kg with the lowest concentration found at station KSHZ03 and the highest at KSUR01. The values obtained from 1993 to 1996 monitoring are similar to results obtained from a previous study (WDOH, 1996).

Lead

All detected values were below the RDL (0.4 to 1.0 mg/kg) and most values were below the MDL (0.3 mg/kg). With the exception of the 1.0 mg/kg value (obtained for the bent-nosed clam sample), all

other detected values were very close to the MDL. Lead results are similar to values obtained for other studies (WDOH, 1996; Faigenblum, 1988).

Mercury

Mercury was detected in all but two samples, but at concentrations below the RDL. Concentrations ranged from 0.004 to 0.014 mg/kg. The highest concentrations were found at stations KSSN04 and KSUR01, which had mean concentrations from 1993 to 1996 of 0.010 and 0.011 mg/kg, respectively. These results are lower than those found in previous studies by WDOH (1996), Tetra Tech (1988), and Faigenblum (1988) who found mercury concentrations in native littleneck clams from 0.01 to 0.06 mg/kg.

Nickel

Nickel was detected in all but one sample, but below the RDL for the majority of the samples analyzed. Concentrations ranged from less than the MDL (0.40 mg/kg) to 1.67 mg/kg, with one exception. The sample at station KSJX02 in 1994 (consisting of bent-nosed clams) had a value of 14.50 mg/kg, which is almost nine times higher than the next highest value. At noted for chromium, this difference can be attributed to species composition of the sample. Nickel is a trace metal not often analyzed in clams, and therefore, comparisons with other studies are not possible.

Silver

Silver was detected in most samples at concentrations above the RDL. Values ranged from less than the MDL (0.08 mg/kg) to 2.18 mg/kg. The highest concentration was detected at station KSSN04. Similar values were found for all years.

Zinc

Zinc was detected in all samples above the RDL for all years. Values ranged from 6.4 to 19.0 mg/kg. Concentration ranges were similar for all four years. The highest concentration was found at station KSUR01. This station also had the highest mean concentration (15.0 mg/kg) between 1993 and 1996. Concentrations detected are similar to those found in other Puget Sound studies (WDOH, 1996; Faigenblum, 1988).

Discussion

Yearly mean trace metal concentrations (all sites combined) varied only slightly between 1993 and 1996 and the highest concentration for any specific metal was not consistently found at one particular site. Of the nine metals presented in this paper, chromium, copper, silver, and zinc were detected above RDLs in most of the clam tissues analyzed from all eight sites and for all years (1993–1996). Copper, chromium, and zinc were detected in all samples; however, chromium concentrations were below the RDL but above the MDL for three samples. Silver concentrations were above RDLs for all but six samples and were not detected in two samples collected in 1994. These results suggest that copper and zinc tend to bioaccumulate to a greater extent than other metals, which agrees with results obtained from other bivalve studies in Puget Sound (WDOH, 1996; Faigenblum, 1988).

State and federal criteria do not exist for acceptable levels of trace metals in shellfish tissues. The U.S. Food and Drug Administration (FDA), however, has established guidance values termed Levels of Concern for both mollusks and crustaceans for five metals: arsenic, cadmium, chromium, lead, and zinc. These guidance values are risk-based and differ for adults and children. To compare results obtained from King County beaches, the lower of the two guidance values for mollusks was chosen. For chromium, this guidance value is 11 mg/kg, which is well above the concentrations obtained from King County monitoring of edible clams (FDA, 1993a).

Table 1. Trace metal data for clam tissues.

Locator	Date Collected	Arsenic (mg/kg wet wt.)	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc
KSHZ03	Sep-93	2.5	0.10	0.27	1.90	<MDL (0.3)	0.008	0.50	1.20	12.0
	Jul-94	1.3	0.21	0.21	0.89	<MDL (0.6)	0.004	<MDL (0.4)	<MDL (0.08)	15.0
	Jul-95	2.0	0.27	0.37	1.58	<MDL (0.3)	0.005	0.34	0.07	12.5
	Jul-96	1.8	0.25	0.19	0.95	<MDL (0.3)	0.007	0.31	0.31	13.1
	Mean:	1.9	0.21	0.26	1.33	<MDL	0.006	0.38	0.52	13.2
KSJX02	Sep-93	1.0	0.10	0.20	1.60	0.4	0.005	0.80	1.00	7.5
	Jul-94 *	2.4	0.10	31.30	3.19	1.0	0.008	14.50	0.16	15.7
	Jul-95	1.8	0.16	0.50	1.41	<MDL (0.3)	<MDL (0.004)	0.48	0.12	7.4
	Jul-96	2.1	0.22	1.02	1.90	0.5	0.007	1.22	1.74	6.4
	Mean:	1.8	0.14	8.26	2.03	0.6	0.007	4.25	0.76	9.2
KSLU03	Sep-93	2.0	0.08	0.38	2.70	0.4	0.007	0.80	1.20	14.0
	Jul-94	1.8	<MDL (0.06)	1.02	1.76	<MDL (0.6)	0.006	1.10	0.52	10.4
	Jul-95	2.1	0.05	1.13	1.16	0.5	0.004	0.97	0.11	7.7
	Jul-96	2.8	0.09	0.34	2.08	<MDL (0.3)	0.006	0.92	1.08	17.6
	Mean:	2.2	0.07	0.72	1.93	0.5	0.006	0.95	0.73	12.4
KSSN04	Sep-93	2.7	0.07	0.53	2.20	<MDL (0.3)	0.010	1.00	1.80	13.0
	Jul-94	2.5	0.09	0.62	2.22	<MDL (0.6)	0.010	1.10	1.88	11.7
	Jul-95	2.8	0.07	0.48	1.85	<MDL (0.3)	0.007	0.83	0.89	14.7
	Jul-96	3.4	0.09	0.44	4.72	<MDL (0.3)	0.012	0.92	2.18	14.3
	Mean:	2.9	0.08	0.52	2.75	<MDL	0.010	0.96	1.69	13.4

Table 1. (continued)

KSSN05	Sep-93	2.0	0.10	0.55	2.00	0.4	<MDL (0.004)	1.00	0.10	10.0
	Jul-94	1.6	0.21	1.11	1.72	<MDL (0.6)	0.005	1.20	<MDL (0.08)	12.5
	Jul-95	3.1	0.09	0.48	2.14	<MDL (0.3)	0.008	0.74	0.92	15.4
	Jul-96	1.3	0.19	1.42	1.97	0.5	0.005	1.67	0.08	8.2
	Mean:	2.0	0.15	0.89	1.96	0.5	0.006	1.15	0.37	11.5
KSUR01	Sep-93	2.0	0.10	0.66	5.10	0.4	0.010	1.20	0.28	19.0
	Jul-94	2.6	0.08	0.68	2.60	<MDL (0.6)	0.010	0.83	1.32	13.2
	Jul-95	3.4	0.04	0.60	2.91	<MDL (0.3)	0.009	0.77	1.90	13.6
	Jul-96	2.9	0.07	0.41	1.65	<MDL (0.3)	0.014	0.91	1.45	14.0
	Mean:	2.7	0.07	0.59	3.07	0.4	0.011	0.93	1.24	15.0
LSKR01	Sep-93	2.0	0.15	0.69	3.10	0.6	0.006	1.20	1.20	11.0
	Jul-94	3.2	0.11	0.61	1.57	<MDL (0.6)	0.009	0.86	1.20	13.9
	Jul-95	1.6	0.20	0.94	1.28	<MDL (0.3)	0.005	0.94	0.56	8.3
	Jul-96	3.1	0.08	0.41	2.04	<MDL (0.3)	0.007	0.78	0.97	12.7
	Mean:	2.5	0.14	0.66	2.00	0.6	0.007	0.95	0.98	11.5
LSKS01	Jul-94	2.4	<MDL (0.06)	0.85	1.51	<MDL (0.6)	0.007	0.92	0.83	13.4
	Jul-95	2.4	0.14	0.51	1.37	<MDL (0.3)	0.006	0.75	0.66	11.8
	Jul-96	3.1	0.06	0.29	1.78	<MDL (0.3)	0.007	0.71	0.68	12.1
	Mean:	2.6	0.10	0.55	1.55	<MDL	0.007	0.79	0.72	12.4

Highlighted values were below the reported detection limit but above the method detection limit (MDL).
*Indicates sample was composed entirely of a non-target species, *Macoma nasuta*.

Arsenic, cadmium, and nickel were detected in most samples, but at concentrations below the RDLs. The results are in agreement with arsenic and cadmium values obtained from other Puget Sound studies (WDOH, 1996; Cubbage, 1991). Nickel is not a trace metal often reported, and therefore, comparisons with other Puget Sound studies cannot be made. The FDA Levels of Concern for arsenic, cadmium, and nickel are 55, 3, and 80 mg/kg, respectively (FDA, 1993b, 1993c, 1993d). Results from our sampling efforts are well below these guidance values for all three metals.

Mercury was detected in most samples, however, all concentrations were below the RDL and the mean concentration at each site between 1993 and 1996 was 0.01 mg/kg. The FDA has established an Action Level (above which a food product cannot be commercially traded) in fish and shellfish tissues of 1.0 mg/kg for mercury (FDA, 1985). When this value is exceeded, the food product cannot be commercially traded which is how an Action Level differs from a Level of Concern. All sample results from this study were well below this Action Level. Results are similar to results from previous studies in Puget Sound, which also found values close to analytical detection limits (WDOH, 1996; Cubbage, 1991).

Lead was only detected in eight samples and at concentrations below the RDL. These results are similar to those from previous studies, although the detection limits for our samples were higher than other studies (WDOH, 1996; Faigenblum, 1988). The FDA Level of Concern guidance value for lead is 0.8 mg/kg. All results obtained for edible target species were below this value.

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